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GESTURE-DIRECTED SENSOR-INFORMATION FUSION (GDSIF) FOR PROTECTION AND COMMUNICATION IN HAZARDOUS ENVIRONMENTS

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ABSTRACT – This position paper describes a vision of how Chemical Biological Radiological and Nuclear (CBRN) situation awareness and threat assessment [1], [2] can benefit from the use of Gesture-Directed Sensor-Information Fusion (GDSIF). It describes a concept of operations for the war fighter's use of electronic wireless-communication gloves (eGloves) to communicate, plan, and react while wearing Mission-Oriented Protective Posture (MOPP) gear. It also suggests the benefit of using the hardware and firmware resident on the eGloves to perform data fusion from environmental sensors. It provides a roadmap of research issues and challenges that will need to be overcome to realize this technological advance.

INTRODUCTION

The battlespace is full of threats that would be better to detect earlier rather than later. War fighters are in the best position to detect CBRN threats in theatre. Current Chemical-protection for war fighters on the ground inhibit electronic communication via keyboards, cell phones, and remote-control devices. War fighters need better communication methods in hazardous environments characterized by CBRN agents. Important topics in wartime communications include but are not limited to situation and threat assessments. To improve communications capabilities for the war fighter wearing protective gear in hazardous environments, a series of eGloves have been developed with a view toward freeing the war fighter of the need to type on a keyboard while wearing a MOPP suit. (See, for example, [5] and [6].) These eGloves can help the warfighter transmit gestures with the hands and fingers from within the protective gear [5], [6], or they can be used to transmit encoded ASCII characters [5]. Fig. 1 shows an eGlove prototype.

Fig.1. eGlove with motion sensors and CPU circuitry

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This position paper describes a vision of how Chemical Biological Radiological and Nuclear (CBRN) situation awareness and threat assessment [1], [2] can benefit from the use of Gesture-Directed Sensor-Information Fusion (GDSIF). It describes a concept of operations for the war fighters use of electronic wireless-communication gloves (eGloves) to communicate, plan, and react while wearing Mission-Oriented Protective Posture (MOPP) gear. It also suggests the benefit of using the hardware and firmware resident on the eGloves to perform data fusion from environmental sensors. It provides a roadmap of research issues and challenges that will need to be overcome to realize this technological advance. Published in Proceedings, DTRA Chemical and Biological Defense S&T Conference, 16-20 Nov. 2009, Dallas, TX

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Research has demonstrated that chemical and biological sensors can be made smaller, more sensitive, more species specific, and easier to deploy in a variety of ways. (See, for example, [1] and [3].) The current eGloves have magnetic and motion sensors for gesture recognition [5], [6]. An important future step to enhance the effectiveness of the war fighter is to integrate CBRN and other sensors into the eGloves. Development of efficient data-fusion algorithms to fuse the information from CBRN and other sensors with gestures from the eGlove operator will provide SA beyond the readings from individual sensors. The following sensors could be integrated with gestures transmitted using the eGlove: CBRN sensors, acoustic sensors, Geo-positional sensors(GPS), optical sensors, physiological sensors to monitor the health of the operator, and imagery sensory input from video cameras mounted in various strategic locations in the environment. The output of these passive sensors can be transmitted along with the magnetic/motion sensor output. This will improve communications by providing explicit measurements or information without burdensome and error prone manual relay. Integrating the environment sensor data with the current eGlove gesture software would expedite communications by providing contextual information to the glove. For example, if the physiological sensors on the glove are detecting values beyond normal thresholds, different communications suggestions could be presented than during normal operating conditions.

DESCRIPTION AND BENEFIT

Gesture-Based Sensor-Information Fusion (GBSIF) refers to the fusing of sensor data collected from the environment with data from motion sensors on the eGlove. The eGlove features a CPU that is used to fuse hand and finger motions and positions into gestures, as shown in Fig. 1. The same CPU can be used to fuse additional data from the environment. In GBSIF, the operator transports the sensor array but does not take an active role in determining the sensors that will participate in the fusion or the target subjects about which the data will be collected, with the exception of the sensors mounted on the eGlove. Data are collected from the environment and also from the glove sensors, and these data can be fused and integrated on a network site that differs from the user's node. Thus, gesture sensor data and environmental data are collected, fused, and integrated where appropriate. However, the gestures themselves are not the primary driving force in selecting information sources and controlling the fusion process.

In contrast, Gesture-Directed Sensor-Information Fusion (GDSIF) includes GBSIF but extends it to the active participation of the eGlove operator to initiate sensor-information fusion. The concept of operation of the GDSIF is that the war fighter would point to a platform or another object in the battle space using a gesture while wearing a GDSIF-equipped eGlove. The eGlove would be linked to reference sensors to determine orientation and azimuth of the operator's arm. The eGlove also would use GPS to determine the operator's geographic location. Gestures would cue sensors to send their data to the eGlove where these data would be fused with the gesture that prompted the data collection. Fusion would be accomplished in the CPU mounted on the eGlove. Our preliminary experiments show that the current CPU will support additional sensors without difficulty. Of the many options for accomplishing this, the three subsequent architectures provide the best advantages.

1. Tracking the date-time group of the sensor data, the GPS geographic location, and the sensor type will provide the pedigree metadata [2] necessary to sort and fuse the information. CBRN, acoustic and GPS sensors can be mounted on the eGlove and the CPU can collect and fuse data from all sources on the eGlove. The CBRN, acoustic and GPS sensors would detect

environmental conditions but not health-related conditions of the operator. Redundant sensors mounted on the eGlove could help reduce problems due to false alarms of any one sensor. CBRN Sensors with heightened sensitivity could transmit detection even before the war fighter is aware of the presence of a chemical or biological agent. These networked and fused sensors could provide warnings and alerts to be sent not only to the operator but also to the wireless network with which the operator is in communications. When applicable, these alerts could be localized to prevent 'noise' being sent to unaffected parties. This could be used to alert and send early emergency response team independent of any specific request from the war fighter.

2. Same as 1, but in addition to external sensors, the eGlove also would detect physiological data of the operator, such as pulse and Galvanic skin response (GSR). For example, if the chemical detectors sent signals about a plume and the operator did not transmit any gestures determined to have intent or meaning, this could mean that the chemical agent had attacked and incapacitated the operator. The pulse and other physiological signals could help determine the operator's health.

3. The CPU mounted on the eGlove could be programmed to detect not only local signals from hand and finger gestures but also from a variety of wireless sensors throughout the battlespace. This could include sensors mounted on or deployed from UAVs [3], motor vehicles, or even other war fighters. This provides a wider coverage of the battle space beyond the immediate vicinity of the operator. The obvious disadvantage of these extra sensors is that it adds complexity to the task of the CPU on the eGlove. The challenge is to develop effective data-fusion algorithms to manage the data streams and the metadata from an increased number and variety of sensors in the battle space.

The operator could select a 1) "Raw-data-only mode" to transmit the data to the wireless network, or 2) "fuse data" mode in which algorithms stored in the eGlove's CPU would perform data fusion and then transmit the fused-data result to the wireless network. The operator could use gestures to control multiple modes of operation of the eGlove.

GESTURES

Simple gestures can be used to communicate information to improve situational awareness, send commands to personnel and to robots [6], and send commands to CBRN and other sensors in the battle space. For example, the gesture to use most often for information fusion would be to point at a sensor-data source in the battle space with the index finger extended and the other fingers touching the palm, (to distinguish it from similar gestures that use the whole hand to point.) This pointing gesture, when recognized, would signal the sensor and trigger a data stream or a single reading from the designated sensor to the local common-data backbone. Sucessful transmission from the sensor would trigger haptic feedback [5] on the operator's glove indicating that the data set has been sent to the network. Continuing the example, the war fighter could repeat the pointing process with a second sensor and then a second gesture, for example a fist with the arm held straight down, would trigger a pre-determined sensor-information fusion process. Using the fusion-fist gesture in this manner would distinguish it other gestures that employ a closed fist with the arm extended, which in some command contexts means "stop." It also would avoid confusion with gestures in which the fist is held close to the chest.

CBRN sensor-information could be thus queried and fused with each other and also with information from other sources in the battle space, such as electromagnetic or acoustic sensors. In more advanced implementations of this methodology, the war fighter could provide some

degree of input about what type of information is desired from the sensor-information fusion, such as a prediction of routes to use for relatively safe travel with respect to the deployment of CBRN agents.

CHALLENGES

To facilitate GBSIF and GDSIF, the vocabulary, syntax, and semantics of command gestures would be developed to include all possible modes of operation that the war fighter would need. Since the eGlove should be used in a variety of situations, the vocabulary of gestures for GDSIF ideally would build on the vocabulary of gestures already in use for similar purposes. For example, special forces already have gesture-based communication. Human factors and physiology would help determine the ease of using certain gestures rather than others. Special fusion algorithms would be developed to process gesture data and fuse them with environmental data. Advanced operators could be trained to issue gesture commands to determine which fusion algorithms to execute. These are areas that require future research.

Maintaining the integrity and timeliness of the Common Operating Picture (COP) with existing data is already a challenge [4]. Integrating these GDSIF data into the COP where other war fighters could benefit from local observations is an even greater challenge requiring further research and testing. Potentials include integration into the Joint Warning and Reporting Network (JWARN) program of record.

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